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Environmental Legacies of the Vietnam War

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The environmental history of the Vietnam War is unique in the twentieth century for the unprecedented scale of aerial bombing and use of incendiaries such as napalm, as well as the United States military's use of tactical herbicides to destroy forest cover in combat zones. The most widely used herbicide was called Agent Orange, named after the orange stripe on drums containing the herbicides 2,4,5-T and 2,4-D. Specially equipped US Air Force cargo planes covered about one-third of South Vietnam's forests with some 21 million gallons of the herbicide. When reports surfaced in 1969 and 1970 suggesting that a dioxin contaminant in it caused birth defects, environmental and antiwar activists joined forces, labeling this intentional destruction of Vietnam's forests and widespread toxic exposure "ecocide."[1] The Hanoi government repeatedly decried the herbicide-spraying as a war crime violating the 1925 Geneva Protocol banning the use of chemical weapons. After the war, as more veterans reported strange illnesses, class-action lawsuits erupted that held American public attention in the 1980s until, in 1991, the US Congress passed an Agent Orange Act guaranteeing funding for independent scientific research and health care for veterans, at least for US veterans. For the 3–4 million Vietnamese who were exposed to the toxic hotspots where tactical herbicides had leaked into the ground, there was minimal medical support and little in the way of cleanups, until very recently. These two issues, responding to health claims and remediating hotspots, remained top level for over thirty years of US–Vietnam relations, and only in the past decade have both sides reached new agreements as the United States has committed more than $300 million for remediation efforts at its former bases.[2]

1 See David Zierler, *The Invention of Ecocide: Agent Orange, Vietnam and the Scientists Who Changed How We Think about the Environment* (Athens, GA, 2011), 122–3.

2 Of the numerous histories of Agent Orange, Edwin A. Martini's *Agent Orange: History, Science, and the Politics of Uncertainty* (Amherst, MA, 2012) provides a comprehensive account of the legal and political battles in the postwar era, while Alvin Young's *The History, Use,*

The Agent Orange story is unique for many reasons, and it is addressed in more detail below, as well as in several dozen books and documentaries, but this was just one of a broad spectrum of the war's environmental legacies. Drawing on recent trends in environmental and military history, this chapter aims to provide a more comprehensive sketch of the environmental legacies of the Vietnam War. Besides the effects of bombing and herbicides, these include inquiries into the "footprints" of warfare in urban and industrial development, in ethnic and demographic shifts in former war zones, in the dispersion of invasive species, and even in the creation of wilderness or conservation areas. Historians have only recently begun to grapple with a set of military processes called "militarization" that includes not only following events on the battlefield, but also looking at the ways military activity and occupation affect political systems, logistics networks, cultural affairs, tourism, and migration. Feminist scholar Cynthia Enloe's studies on militarism, masculinity, and gender relations, especially in the peripheries of American bases in the Philippines and Okinawa, extends analyses of the American military's influence far beyond the battlefield and the base, exploring military legacies in advertising, sex work, and tourism.[3] This chapter considers the Vietnam War's legacies in a similarly wide-ranging manner but with respect to landscapes and ecosystems. The term "landscape" is used to recognize natural and built environments that are understood in both physical and social or cultural terms. Ecosystems describe mostly physical phenomena, including human activities, and they describe larger webs of environmental events connected to human and nonhuman life, geologic activity, and climatic stimuli.[4] This chapter considers the environmental legacies of the Vietnam War with respect to a wider set of military processes, the varied landscapes of Vietnam, and rapidly changing ecosystems.

The environmental legacies of the Vietnam War extend far beyond areas scarred by bombing or toxic chemicals. Military activities such as base operations, road construction, and population resettlement remade landscapes, from the Chinese border to Thailand, Laos, Cambodia, and the Mekong River Delta. War left indelible footprints on Vietnamese cities, from Soviet- and East German–designed housing blocks built in the North to airports,

Disposition and Environmental Fate of Agent Orange (New York, 2009) provides a comprehensive account of the military's development and use of Agent Orange and other herbicides.

3 Cynthia Enloe, *Bananas, Beaches and Bases: Making Feminist Sense of International Politics* (Berkeley, 2014).

4 I address these issues specifically in Vietnam and not just for the Vietnam War but over Vietnam's long twentieth century. See David Biggs, *Footprints of War: Militarized Landscapes in Vietnam* (Seattle, 2018).

highways, and deep-sea ports built in the South. The war accelerated new trends in agriculture, and it dramatically reworked the ethnic landscapes of Vietnam's Highlands. From an historical perspective, the challenge in studying the Vietnam War's environmental legacies begins with the problem of contextualization. How might one tease out specific impacts from the 1960–75 era versus decades of military conflict that preceded it or events that followed in the Third Indochina War? How did legacies differ from one regional context to another? Many impacts, including those of Agent Orange, were targeted to specific locales, so how can we assess environmental legacies without losing these local particularities of place and ecology?

Timescapes

In environmental history, establishing the temporal boundaries of an environmental event is an important starting point for any study, especially a war, as it concerns agency. Agency in environmental history concerns both human *and* nonhuman actors, from governments and militaries to plants and animals, geology, weather, and climate. There is often a presentist bias in military environmental history that assumes prewar landscapes and environments were stable, for example such tropes as the eternal Vietnamese village or views on preconflict forests as pristine wilderness. Vietnam's early modern history shows that villages and forests were far from stable in this sense and were repeatedly subjected to volatile political and environmental changes. Civil conflicts like the Tây Sơn Rebellion (1778–1802) erupted in part because rural communities in central Vietnam had disintegrated under a mix of ecological and political pressures.[5] This social, economic, and environmental volatility continued in the 1800s, and it contributed to France's military successes in creating the colony of Cochinchina in 1862 and Indochina in 1884. The colonial government targeted newly acquired "empty" spaces, such as delta swamps and the *terres rouges* forests, for "reclamation" and conversion into rice and rubber plantations. These plantation belts shattered traditional, ethnic landscapes as millions of ethnic Vietnamese migrants from the north moved into them. Such spaces became "engines" of the modern, colonial economy, and in the 1930s communist activists targeted them in order to

5 Historians George Dutton and Li Tana highlight the fractures that split rural communities, especially from the Nguyễn Lords who ruled the southern region from Phú Xuân (Huế). See Li Tana, *Nguyễn Cochinchina: Southern Vietnam in the Seventeenth and Eighteenth Centuries* (Ithaca, 1998) and George Dutton, *The Tây Sơn Uprising: Society and Rebellion in Eighteenth-Century Vietnam* (Honolulu, 2006).

attract thousands of supporters from the working poor.[6] The Việt Minh and, later, the National Front for the Liberation of Southern Vietnam (NLF, or Viet Cong) led military assaults on these spaces in the French Indochina War and the Vietnam War, culminating in devastating battles such as Operation Junction City (February–March 1967) that involved tens of thousands of troops and became one of the largest airmobile assaults in modern warfare. Returning to the question of agency and temporal boundaries, the *prewar* environmental history of such places as the Michelin Rubber Plantation, located some 45 miles (75 kilometers) north of Saigon, mattered greatly in shaping the place of the 1967 offensive. This rubber-plantation landscape possessed a type of agency in drawing communist military units and held a key strategic value to them and their American adversaries.

Attention to environmental prehistory is important when studying the *legacies* of the Vietnam War, because it establishes longer-term patterns of urban and rural development in Vietnam that ebbed and flowed beyond the staccato disruptions of military events. In the example above, prewar activities such as the colonial-era development of rubber plantations and the rise of communist cells among plantation workers in the 1930s played formative roles in attracting NLF cadres to the area in the 1960s. This dynamism was also important to postconflict legacies; communist cadres saw the rubber plantations as key to *their* nation-building ambitions, too. American military actions such as widespread bombing and defoliation had the short-term effect of destroying thousands of hectares of rubber trees, but these violent "openings" also accelerated the Socialist Republic of Vietnam (SRVN)'s effort to reestablish rubber plantations by clearing forests and opening up thousands more hectares. State-owned and later private companies took advantage of the war's disturbances to expand the industry, as indigenous communities were shattered and thousands of People's Army of Vietnam (PAVN) veterans agreed to settle there. At the same time that these new migrants settled in the *terres rouges*, they also were unwittingly exposed to the residues of toxic chemicals and unexploded bombs, so the "legacy" of the war here was mixed. Now, almost fifty years since the war's end in 1975, the effects of chemical exposure and unexploded ordnance have largely subsided and given way to a decades-long process of "re-greening," where wild forests of dipterocarps and other old-growth species have given way to endless, green rows of rubber trees.

6 See Michitaki Aso, *Rubber and the Making of Vietnam: An Ecological History, 1897–1975* (Chapel Hill, NC, 2019).

The term "timescape" is a relatively new invention introduced by scholars interested in the long-term effects of toxic accidents, but scholarly interest in this issue of temporal agency between war and the environment goes back more than a century.[7] Historians of the Roman empire, for example, noted that military occupations such as the Emperor Claudius' troops camping around a strategic bridge crossing the River Thames in 43 CE gave rise to a nucleus of markets outside the camps that grew into the City of London. On the Red River in northern Vietnam, a similar urban polity grew up around a series of Chinese citadels located on both banks of the Red River in what is now downtown Hanoi. However, it was only in the early twentieth century that historians and social scientists began to consider how wartime disruptions might stimulate major economic and environmental shifts. German economist Werner Sombart published in 1913 a sort of prowar book titled *Krieg und Kapitalismus* that pointed to the destruction of forests in Prussia's 1870 war with France as key to the postwar rise of industrial society in the Ruhr Valley and the creation of the German state.

Sombart and his German "historical school" colleagues, however, were unprepared for the scale of destruction that swept the Western Front from 1914 to 1918; but one idea that Sombart cribbed from Friedrich Nietzsche, *creative destruction*, lived on in economic circles, especially after World War II. This term is especially useful for exploring issues of war's agency in reshaping environments and economies. The Austrian economist Joseph Schumpeter popularized the term in 1942 to explain how disruptions of capitalist business cycles that periodically laid waste to outmoded industries were necessary. American development economists pointed to the economic miracles of West Germany and Japan in the 1950s as confirming the net-positive gains wrought by the United States aggressively investing in the rebuilding of German and Japanese cities and industries. In the 1960s, American economists like Walt Rostow drew from these examples of creative destruction to create what historian Michael E. Latham describes as a modernization ideology. Especially during the Vietnam War, hundreds of American social scientists joined the Kennedy and Johnson administrations to support nation-building in South Vietnam. Even as most of these individuals turned against the war, a few – like the Harvard political scientist Samuel Huntington in 1968 – continued to

7 Barbara Adam's *Timescapes and Modernity: The Environment and Invisible Hazards* (London, 1998) is one of the first works to focus on the centrality of time in understanding environmental issues; and more recently Rob Nixon's *Slow Violence and the Environmentalism of the Poor* (Cambridge, MA, 2013) pays closer attention to the politics of state responses to toxic events.

Figure 21.1 Four US Air Force Ranch Hand C-123s spray a communist jungle position with defoliating liquid (September 30, 1965).
Source: Bettmann / Contributor / Bettmann / Getty Images.

argue that the increasingly horrific scale of aerial bombing, unprecedented in the history of warfare, would in the end produce a new, more urban society. He infamously justified American practices of carpet-bombing in South Vietnam for causing this "forced draft urbanization."[8]

This attention on war's agency in shaping postwar environments and concerns about the relative timescapes of these changes are also tied to another relatively new concept in global environmental history: what some have termed the Great Acceleration. The Great Acceleration refers to dramatic surges in growth rates for a wide variety of human activities that, in turn, have affected global climate and advanced social processes called "globalization." Major factors in this acceleration include the shift in energy regimes from relying on manual labor, animal draft power, and foot travel to reliance on fossil fuels, internal

8 Samuel Huntington, "The Bases of Accommodation," *Foreign Affairs* 46 (4) (1968), 642–56.

combustion engines, and motorized transport.[9] Historians of the Vietnam War have yet to analyze the war within this framework of the Great Acceleration. One of the most impressive constructions by communist forces, the network of trails and supply lines called the Hồ Chí Minh Trail, offers a unique site for examining this Great Acceleration in Vietnam. US President Lyndon B. Johnson's call for bombing of the North in Operation Rolling Thunder in 1965 was a calculated effort to thoroughly demoralize North Vietnam's leaders and people by showing the modern, destructive capabilities of the American military. While the bombing cost thousands of lives and inflicted unprecedented damage, it also bolstered the decision of the ruling Politburo to engage in a "total war," in which hundreds of thousands of young men and women joined in efforts to expand the Hồ Chí Minh Trail.[10] From 1964 to 1975, the nature of the fighting, especially the bombing campaigns, accelerated the construction of a Vietnamese network of trails, roads, and small cities into the Highland areas of Vietnam, as well as in eastern Laos and Cambodia. While communist forces may have traveled by foot in the early years, by the late 1960s they had developed ingenious methods to disguise trucks, distribute radio and wired communications, and even to supply petrol through plastic pipelines.

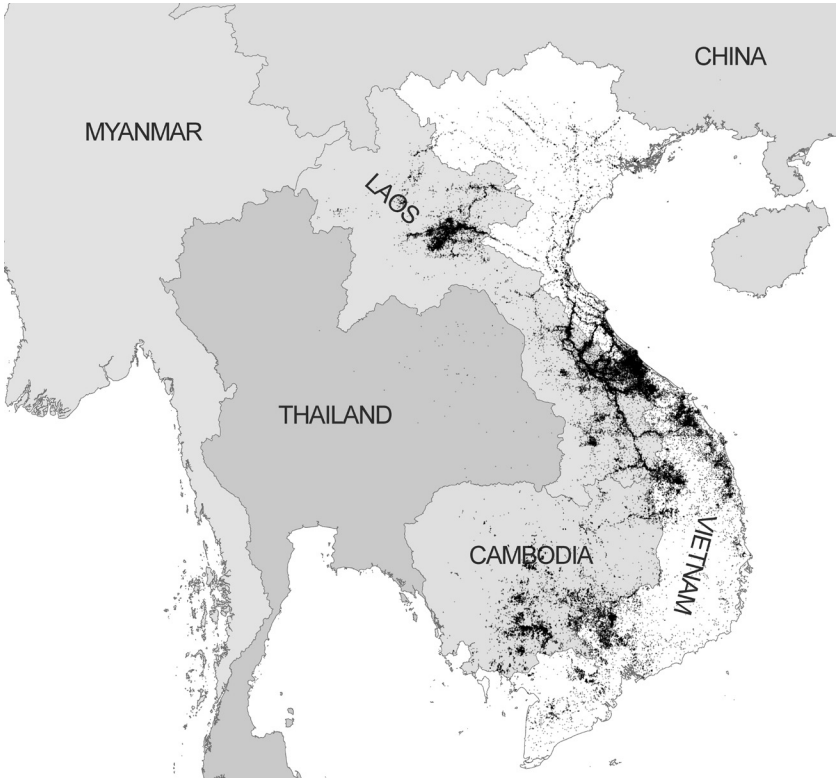
The environmental history of the Hồ Chí Minh Trail is still largely unexamined; but a more multisided examination of the Great Acceleration here suggests that the unimaginable intensity of American military activity, from bombing and defoliation to large-unit battles, had devastating impacts on ecosystems, but also spurred on a response from communist forces. This response continued after the war's end, as veterans of the People's Liberation Armed Forces (PLAF, the armed wing of the NLF) and the PAVN migrated to Highland areas; and they and their descendants have continued to play central roles in the development of these areas through a mix of military and privately owned companies engaged in forestry, mining, and infrastructure development and tourism. Only when a top-secret unit of the US Military Assistance Command, Vietnam (MACV), the Special Operations Group, noted the networks of plastic fuel pipelines running hundreds of miles along these trails in 1968 did the most senior American military planners finally grasp these accelerating effects of bombing on Hanoi's "total war" strategy. In this sense, the Vietnam War accelerated what had before 1945 been a very slow process: the Vietnamese state's expansion into Highland regions.

9 J. R. McNeil and Peter Engelke's book, *The Great Acceleration: An Environmental History of the Anthropocene since 1945* (Cambridge, MA, 2016), provides a highly accessible introduction to these ideas.

10 For an in-depth discussion of decision-making in Hanoi, see Pierre Asselin, *Hanoi's Road to the Vietnam War, 1954–1965* (Berkeley, 2013).

Environmental Legacies in the Many Spaces of the Vietnam War

Another pitfall in assessing the environmental legacies of a war is a certain "geo-body bias," whereby the environmental impacts of such actions as bombing are considered uniformly across a country despite incredible diversity in its geography. Barry Weisberg's 1970 book, *Ecocide in Indochina*,[11] is a good example, for it emphasizes American military operations, such as the use of napalm and Agent Orange, but shows little comprehension about where these events took place. Wars are not fought uniformly across a country but are instead concentrated on strategic spaces, lines of communication, and politically important terrains. Map 21.1, showing



Map 21.1 US bombing missions 1962–75.
Source: Map by author.

11 Barry Weisberg, *Ecocide in Indochina: The Ecology of War* (San Francisco, 1970).

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every American bombing mission undertaken during the war with a total tonnage over 10,000 lbs, highlights this fact, with the majority of heavy bombing missions targeting key routes of the Hồ Chí Minh Trail, especially the major staging areas in Laos and Cambodia.

The environmental legacies of the war, whether American bombing or communist mobilizations, had very different effects depending on the terrain and location. Thus, it is incredibly difficult to consider the environmental legacies of the Vietnam War in any comprehensive sense across Vietnam's entire territory; it makes far more sense to consider the impacts of war in specific regions or terrains.

The Mekong Delta, stretching south and west of Saigon, was a key back-theater of the war that saw comparatively little bombing but was vital to American attempts at nation-building and counterinsurgency. This region was South Vietnam's rice bowl, roughly 5 million hectares of marshes, river branches, and arroyos crisscrossed by almost 6,000 miles (10,000 kilometers) of canals. Even within the delta, there was extensive ecological variation, from giant, bowl-like depressions such as the Plain of Reeds, which was a major base area for the NLF, to riverside cities like Mỹ Tho, which were vital centers for commerce and new initiatives like the introduction of high-yield or "miracle" rice. One of the war's biggest impacts here in the 1960s was a revolution in mechanization. For the first time since the American civil war, the US Navy, along with the army's 9th Infantry, mobilized a brown-water fleet to conduct amphibious operations along the delta's canals and rivers. Until 1970, they operated a giant floating base near Mỹ Tho on the Tiền Giang River. However, the impact of mechanization was felt most by the concurrent import of millions of small motors as part of the United States' economic initiatives. Mỹ Tho became a major center of shops offering 4- and 6-horsepower engines, especially Kohler engines, for use as boat motors or irrigation pumps. Enterprising local mechanics found ways to modify the engines for dual use as "shrimp-tail" outboard motors or, when attached within a water pipe, as a pump for lifting water. The result was a quiet revolution of sorts. A Dutch team visiting the delta in 1975 estimated that as many as 1 million engines were in use, and veterans of the NLF noted the extraordinary impact that these small motors had for their mobilization of troops across the delta's marshes and swamps.[12] While the war left few scars from bombing here, the introduction of small motors radically altered water regimes and the expansion of farming into flood-prone areas.

12 See David Biggs, *Quagmire: Nation-Building and Nature in the Mekong Delta* (Seattle, 2010).

Vietnam's cities, especially Saigon, Đà Nẵng, and Hanoi, experienced major environmental shifts as a result of the war. The dominant disruption in Northern cities was American strategic bombing. Architecturally, heavy bombing of Northern cities such as Vinh produced openings postwar for new residential designs by East German and Soviet architects. Socialist-style housing blocks popped up in the ruins of devastated urban quarters. Anthropologist Christina Schwenkel's *Building Socialism*[13] highlights the intricate ways that these new urban spaces, created in the wake of American bombing, in turn produced new social identities, new urbanisms. Especially in the present, as Vietnamese cities look to raze these old quarters to build high-rises, many urban historians and activists are reconsidering the legacies of socialist-inspired housing blocks.

Vietnam's third-largest city, Đà Nẵng, mushroomed in size in direct response to American-funded base construction that actually began during the French Indochina War. Following the establishment of the US Operations Mission in 1950, American military officials at the embassy in Hanoi and consulate in Saigon began looking for a new airbase that would fall outside the range of Chinese bombers. Indochina's northern bases at Hải Phòng and Hanoi were well within range of Chinese bases on Hainan Island. Americans began funding base development at Tourane (Đà Nẵng) in 1952 as deliveries of US aircraft to French forces increased. After 1954, this aid continued under the guise of "civil aviation" support, so that by 1965 Đà Nẵng's dual runways could handle the largest military and civil aircraft. The commitment of US ground forces in March 1965 commenced with marines landing on the beach at Đà Nẵng, and US military construction battalions or "Seabees" set to work building a deep-water port, communication facilities, and depots essential for the storage of everything from munitions and chemical agents to frozen meats and Budweiser beer. Anthropologist Heonik Kwon's *Ghosts of War*[14] follows the history of the communities that grew up on the fringes of this city of bases around Đà Nẵng. Ethnically it was quite complex. Besides interactions between Vietnamese and American troops, thousands of South Korean troops operated on the periphery of Đà Nẵng and other cities.

Similar expansions of military facilities along the coast of South Vietnam created new urban and port infrastructure in coastal towns, including Quy Nhơn, Phan Rang, Nha Trang, and Saigon. Quy Nhơn and Phan Rang were until 1960 relatively tiny ports that, for most of the French Indochina War,

13 Christina Schwenkel, *Building Socialism: The Afterlife of East German Architecture in Urban Vietnam* (Durham, NC, 2020).

14 Heonik Kwon, *Ghosts of War* (Cambridge, 2013).

were controlled by the Việt Minh. US forces in 1964–5 took control over large swaths of land outside these towns, and built airports and shipping terminals. Nha Trang was South Vietnam's center for its Marine Corps, and nearby Cam Ranh Bay was selected by US planners for construction of a major, deep-water port servicing large ships and submarines. American military construction commenced in Saigon at the river terminal and around Tân Sơn Nhất Air Base in 1965, but after the 1968 Tet Offensive, American forces and the US military command moved north of the city into sprawling bases and logistics hubs in neighboring Đồng Nai province. As in Đà Nẵng, this spate of urban–military expansion has had dramatic environmental legacies with respect to urban environments in Vietnam. Đà Nẵng eclipsed Huế as the commercial center of central Vietnam, and especially in Vietnam's present-day economic boom, it plays an important regional role in Southeast Asia as a logistics hub connecting Laos and northern Thailand to sea terminals. After 1975, the Soviet Union moved its ships into the Cam Ranh Port, and this legacy of the Soviet naval presence has helped to make Nha Trang a favored destination today for Russian tourists. Meanwhile, former American base areas north of Saigon, like the US Army's post at Long Bình, now host some of the world's largest industrial parks and air-cargo facilities. Hồ Chí Minh City will open its new international airport at another former base here, Long Thành, in 2025.

As depicted in most of the literature and movies on the Vietnam War, the Central Highlands and adjacent areas in Cambodia and Laos feature as the primary backdrops for the war's main battles. Still, the Highlands region is incredibly varied in ecological and social terms, and every valley has its own unique social and ecological features. There are 54 recognized ethnic groups in Vietnam and 109 distinct languages, and the majority of this ethnic and linguistic diversity is concentrated in the Highlands of northern and central Vietnam. One of the most important defining features for many upland valleys was the relationship between "headwater" (*nguồn nước*) or "upland" (*miền thượng*) peoples and their "lowland" (*miền hạ*) neighbors. While much attention is placed on the north-to-south movement of troops on the Hồ Chí Minh Trail, east–west links following rivers were equally important. These upland–lowland relationships existed long before the war or the colonial era, and they feature in a number of works on ethnic Kinh/Vietnamese state relationships with the Highlands.[15]

15 In the Northern Highlands, see James Anderson, *The Rebel Den of Nong Tri Cao: Loyalty and Identity along the Sino-Chinese Frontier* (Seattle, 2007); and Christian Lentz, *Contested Territory: Dien Bien Phu and the Making of Northwest Vietnam* (New Haven, 2019). For the Central Highlands, see Oscar Salemink, *The Ethnography of Vietnam's Central Highlanders: A Historical Contextualization, 1850–1990* (Honolulu, 2003).

Similarly, scholars of Laos and Cambodia such as Vatthana Pholsena, Oliver Tappe, and Jonathan Padwe have analyzed these north–south and east–west relationships in the war-torn highland areas outside Vietnam.[16] Historic transit routes linked the Vietnamese coast with the interiors of Cambodia and Laos, and they followed rivers and traversed key mountain passes. As key lines of communication for communist troops, they were primary targets for much of the American military's bombing and defoliation. During the war, these routes facilitated the mass migrations of lowland peoples, especially Kinh/Vietnamese, along with ethnic Khmer and Lao peoples, into Highland communities. During and after the Vietnam War, many soldiers settled here permanently, with many marrying indigenous peoples and establishing new towns. Many communist base areas, such as Nam Đông and A Luôi in Thừa Thiên Huế province, have since developed into towns because they were not only important logistics points during the war, but also ever since. One of the most embattled highways of the war, Highway 9, was an ancient route connecting the Se Pon River and the Mekong River in Savannahket province with the Thạch Hãn River and the South China Sea in Quảng Trị province. This east–west "road" ran just south of the demilitarized zone (DMZ); the US marine base at Khe Sanh guarded the eastern half, while PAVN forces established depots and base areas on the western half in Laos.

Finally, with respect to the *spaces* of the war, they not only included regions of Vietnam and contiguous areas across the border, but also a number of rear areas that have received comparatively little attention. One of the most important external areas in Southeast Asia was northeast Thailand, where US airbases at Udorn, Nakhon Phanom, and Ubon Ratchathani supported much of the bombing missions along the Hồ Chí Minh Trail. US forces also operated around the Thai capital at Bangkok, where the US Embassy was an important nerve center for coordinating military efforts in the larger region. Offshore from Vietnam there were also important maritime anchorages for military forces. Communist forces maintained a north–south "sea trail" for ferrying troops and supplies in and out of estuaries along Vietnam's sinuous coast; and throughout the war, US Navy aircraft carriers and support vessels anchored about 90 miles (145 kilometers) offshore from North Vietnam and used the spot as a base for launching airstrikes.

16 Vatthana Pholsena and Oliver Tappe (eds.), *Interactions with a Violent Past: Reading Post-conflict Landscapes in Cambodia, Laos, and Vietnam* (Singapore, 2013); and Jonathan Padwe, *Disturbed Forests, Fragmented Memories: Jarai and Other Lives in the Cambodian Highlands* (Seattle, 2020).

Finally, the Vietnam War had environmental consequences on the homefront in the United States, especially at sites where logistical support for the war was concentrated. US Seabees managed much of the base construction work in Vietnam, and three NCB centers at Quonset Point, Rhode Island, Gulfport, Michigan, and Port Hueneme, California coordinated much of the logistical support for one of the largest base construction programs of any military force in modern history. The Vietnam War transformed many local economies in the United States and abroad as demands for supplies and support created thousands of military and civilian jobs. This was especially true around naval shipyards, aircraft manufacturing plants, and on the peripheries of large bases such as the US First Marine Division's headquarters at Camp Pendleton. Some 200,000 soldiers trained at this base before deploying to Vietnam, and in 1975 Pendleton was the first American base to receive thousands of Vietnamese refugees.

The American closure of bases in Vietnam beginning in 1971 and ending in 1973 had major environmental consequences for base landscapes in Vietnam as well as overseas. In Vietnam, the sudden closure of once-sprawling bases such as the army's Camp Eagle near Huế in 1972 left the formidable base city, which had hosted five helipads and some 15,000 troops, in ruins. The South Vietnamese government responded with alarm at the condition of these newly transferred bases, noting the ruins of wrecked machinery, hastily covered waste dumps, and largely unusable infrastructure. American contractors responsible for everything from water and electricity to perimeter lighting systems pulled out their equipment with the troops.[17] The abandonment of the bases, first by Americans and then in March 1975 by South Vietnamese troops, left several dozen ghost towns mostly lining the coastal Highway 1, from the DMZ south to the Mekong Delta. The end of the Vietnam War also affected base environments and local economies in the United States. Thousands of workers were laid off as the US government mothballed ships and transferred base properties like Quonset Point to economic development authorities.

Bombing Legacies

No place in history endured as much concentrated bombing as did Indochina in the Vietnam War, especially along the deeply contested Highland trails. Out of 1.5 million recorded bombing missions, more than 800,000 involved

17 Biggs, *Footprints of War*, 183–6.

conventional or general-purpose bombs, which produced roughly 50 percent of the total tonnage of all bombs dropped, 7.5 million tons. Of the conventional bombs, roughly 75 percent were dropped in high-altitude bombing strikes carried out by the long-range strategic B-52 bomber. Each plane was capable of carrying up to 70,000 lbs of bombs, and most missions involved five or six bombers taking off from a US base in Guam or, later in the war, from Thailand. For given targets, usually key logistical points along the Hồ Chí Minh Trail, the planes collectively could drop between 200,000 and 400,000 lbs of bombs, with 500- and 750-lb bombs being the most common. These were unguided bombs filled with various compounds containing trinitrotoluene (TNT) and ranged in weight from 250 to 2,000 lbs. As with aerial bombing in previous wars, one of the biggest drawbacks to these munitions was the collateral damage caused as they drifted beyond specific military targets. Average accuracy for high-altitude bombing missions was roughly 50 percent. The practice of saturation or carpet-bombing along the Hồ Chí Minh Trail and on certain North Vietnamese cities turned forests, fields, and towns into cratered moonscapes. The Vietnam War was exceptional for the scale of conventional bombing.[18] Roughly 3.5 million tons of conventional bombs fell over Indochina, compared with about 2 million tons dropped in all theaters of World War II. Exploding bombs pulverized the ground into craters ranging 50–200 meters in size, and they sent deadly shrapnel flying up to 400 meters from the blast point.[19] Conventional bombing was most concentrated on the major supply routes for the PAVN and at such key junctions of the Hồ Chí Minh Trail as Xepon in Laos. Women volunteers serving in logistics units like the PAVN's 559th Transportation Battalion suffered especially high casualties because they camped at fixed locations along the trails. Director Lưu Trọng Ninh's popular 1997 film, *Ngã ba Đồng Lộc* (The Girls of Dong Loc Junction), tells the story of ten women aged 17–24 years who were killed when a single bomb struck their cave in 1968.

Besides conventional bombing, antipersonnel munitions or cluster bombs left some of the most pernicious legacies of the war in rural communities,

18 These statistics are derived from analysis of the US Air Force Theater History of Operations database, providing details of every logged bombing mission undertaken by US forces. For details about the creation of the THOR GIS, see Sarah Loicano, "US Air Force: Historic Airpower Database Now Online": www.af.mil/News/Article-Display/Article/466817/historic-airpower-database-now-online/. The air force no longer provides public access to this database, but it is available as an open-source dataset at data.world – "Vietnam War THOR Data": https://data.world/datamil/vietnam-war-thor-data.

19 Joseph Hupy, "The Environmental Footprint of War," *Environment and History* 14 (2008), 405–21.

especially in the hills of Indochina. Whereas unexploded, conventional bombs in the 250–2,000 lb range were large-sized and therefore relatively easy to detect, antipersonnel cluster bomblets were tiny and easily missed. One cluster bomb contained hundreds of tennis ball–sized bombs designed to spread far on impact and then detonate, each spreading enough shrapnel to kill several people. American forces used these munitions along the supply routes of the Hồ Chí Minh Trail, especially in the mountains of Laos, and an estimated 80 out of 270 million bomblets did not explode on impact. Again, considering the issues of scale and time, the fruit-sized shapes of these tiny, unexploded bomblets laying buried over several million acres of hillside have proven most difficult to remove, and because of their shape they especially appeal to children.[20] Similar to antipersonnel cluster bombs, land mines were ubiquitous in the war and used by all sides, usually deployed by ground forces to secure perimeters and no man's lands around camps. Land mines presented less of a postwar hazard than bomblets along the former Hồ Chí Minh Trail, but when the Third Indochina War broke out between the Khmer Rouge and the PAVN, landmine use escalated in Cambodia's northwest provinces.

Chemical Legacies

The chemical legacies of the war not only included the highly controversial herbicide Agent Orange, but also two very common chemical agents: incendiary bombs known as napalm and helicopter-dropped barrels of highly concentrated tear gas. Napalm was invented by chemists at Harvard University in 1942 and became an ideal munition for Allied airstrikes in Europe and Japan, with one single night's strike on Tokyo March 9–10, 1945 killing an estimated 100,000 civilians. Napalm is made from relatively common ingredients: gasoline fuel and a gelling agent made from a combination of a petroleum distillate (naphthenic acid) and palm oil (palmitic acid). In the Vietnam War, besides US jets dropping napalm munitions, the US Army Chemicals Corps employed a tactic called a "flame drop," where cargo helicopters dropped a dozen or more 55-gallon drums of napalm over a suspected enemy base or encampment.[21] As an incendiary, napalm burned off on impact and left relatively few physical remains. Images of napalm strikes, especially a photograph of an accidental South Vietnamese strike hitting a village north of

20 Poet and anthropologist Leah Zani addresses the legacies of antipersonnel munitions in Laotian towns in *Bomb Children: Life in the Former Battlefields of Laos* (Durham, NC, 2019).

21 For a history of napalm, especially its use in the Vietnam War, see Robert M. Neer, *Napalm: An American Biography* (Cambridge, MA, 2013), 109–25.

Saigon in 1972, became some of the most recognizable images of the war. Nick Ut's photograph of that strike, especially an image of napalm burning 9-year-old Phan Thị Kim Phúc, was titled "The Terror of War" and won a 1973 Pulitzer Prize.

While the use of napalm has figured prominently in images and debates since the early 1970s, another major chemical munition, CS gas, has remained largely absent. This is no doubt due to a widespread understanding that tear gas, in most circumstances, is nonlethal, a riot-control agent. However, American troops used it in such massive and concentrated forms that it did cause death by asphyxiation; and after the war, buried caches of CS in metal drums remained a toxic legacy for communities that often had no knowledge of their existence. During the war, US Army Chemical Corps units arranged bulk drops of CS in its powdered, concentrated form to penetrate underground bunkers and tunnel systems. They prepared "smoke drops" similar to "bulk flame drops," where a "Chinook" CH-47 cargo helicopter dropped a dozen or more 55-gallon drums filled with CS and connected to small explosive fuses that detonated the barrels just before impact, spreading the dust into a giant cloud. Communist forces hiding in tunnels reported that soldiers who couldn't escape in time died of asphyxiation, as the powdered concentrate stuck to tunnel walls, their clothes, and their airways.[22] Even fifty years later, buried drums of CS are still found intact at waste sites in Vietnam, Cambodia, and Laos.

Of all chemical agents used in the war, Agent Orange, together with two other herbicides, Agent White and Agent Blue, has received the most attention not only for its targeting of ecosystems, but also for the dioxin contaminant associated with dozens of illnesses. Agent Orange comprised the bulk of the US military's tactical herbicide program known as Operation Ranch Hand. The term "tactical" is important, because what most differentiated these herbicides from commercial ones available throughout the United States and the West was *not* their chemistry but their intended *end use*. Agent Orange was a 50/50 blend of two commercially popular, broadleaf herbicides: 2,4,5-T and 2,4-D. The term "broadleaf" meant that they were designed to kill plants with broad leaves such as tree saplings and weeds, but to spare grasses, including bamboo and grain crops such as rice. This feature made both herbicides very popular in the 1950s for use on golf courses, roadsides, and farms.

Even though scientists working for the military first tested these herbicides during World War II, they didn't scale up production in time before

22 Biggs, *Footprints of War*, 170–3.

the atomic bombings in Japan. Just weeks after the Japanese surrender, one worker from a Philadelphia-area chemical company filed a patent for "herbicides," and after much legal wrangling and the passage of national legislation governing pesticide use in 1948, companies such as Dow, Monsanto, and Dupont began manufacturing herbicides. The two herbicides in Agent Orange became the most common and most popular herbicides on the market by 1960. Against this background of a boom in "commercial" herbicides, part of the Green Revolution, the US Army commenced studies on the "tactical" uses of herbicides in Vietnam to reveal enemy lines of communication and deny them forest cover. In 1963, military researchers created a specification for a 50/50 blend of these two herbicides, naming this specification "Agent Orange" after a requirement that chemical manufacturers paint an orange stripe on the drummed chemical to distinguish it from two other herbicides, Agent White and Agent Blue. White was, like Orange, a broadleaf herbicide but, instead of the dioxin-laced 2,4,5-T, it blended 2,4-D with a different herbicide made by Dupont called picloram.[23] Agent Blue was designed specifically to kill grasses, meaning bamboo and especially rice fields, and its active ingredient was an arsenical herbicide. All of the color names for tactical herbicides derived from the army's military specifications, or "milspec," as a means to tell them apart.

Because these otherwise commercially available herbicides were, like napalm, CS gas, and bombs, destined for tactical or combat uses, their entire history, from initial production at American factories to shipping, storage in Vietnam, use in combat zones, and disposal, was documented separately from *nontactical* chemicals, including the very same herbicides destined for conventional uses. In other words, the same, dioxin-contaminated herbicide, 2,4,5-T, was being used in the 1960s by homeowners, farmers, and groundskeepers. American military forces used commercial herbicides containing 2,4,5-T at air bases such as Andersen AFB in Guam. What this labeling difference means with respect to environmental legacies of the Vietnam War is that a highly detailed paper trail exists for the dioxin-laced Agent Orange, documenting every mission and the location of almost every barrel produced, while records detailing the decades-long use of commercial 2,4,5-T herbicides along runways, roads, and golf courses are largely absent. This uncertainty about associations of the highly toxic 2,3,7,8-TCDD dioxin to either Agent Orange

23 Besides Young's (2009) comprehensive study, for this background, see David Biggs, "Following Dioxin's Drift: Agent Orange Stories and the Challenge of Metabolic History," *International Review of Environmental History* 4 (1) (2018), 7–31.

or a commercial source continues to surface in such places as Okinawa, South Korea, and Guam, where the US military denies using Agent Orange, and records detailing commercial herbicide use are largely absent.

The legacy of Agent Orange and the tactical herbicide program is so well covered in books, documentary films, and ongoing scientific studies that it greatly overshadows all other stories of the war's legacies. An active dialogue about ecocide and the toxicity of Agent Orange accompanied the program throughout the war, as scientists, military experts, and public groups studied their effects. After the war, Vietnamese and American scientists and policymakers continued a series of studies and dialogues, while American veterans experiencing clusters of cancers and children born with severe birth defects joined a class-action lawsuit suing the chemical companies.[24]

Besides herbicides, American troops introduced large quantities of insecticides, including the synthetic organic compound Dichlorodiphenyltrichloroethane (DDT). Like the phenoxy herbicides in Agent Orange, DDT began as a product of American military research in World War II. It proved extremely effective in stopping insect-borne illnesses such as malaria, dengue fever, plague, and typhus by killing insects.[25] The US Army's Chemical Corps platoons, the same units tasked with preparing napalm and CS drops in combat zones, also coordinated regular spraying of bases and "showers" for routine decontamination. Sprayer planes and trucks routinely fogged American base cantonments, and US aid programs introduced DDT and other insecticides to South Vietnam as commercial imports.

Conclusion

Besides these multiple elements and approaches to the environmental legacies of the war, consideration is due to the ways in which public responses to news of saturation bombing, incendiaries, and herbicides have contributed to global environmental movements since the early 1970s. The Agent Orange issue in many respects catalyzed public attention in 1970 because it merged public interests in two previously unrelated issues: anger over the war in Vietnam and public concern about oil spills, toxic waste, and the environment. On January 1, 1970, the National Environmental Policy Act took effect, establishing requirements for all federal agencies to produce environmental assessments,

24 For their detailed histories of wartime debates on ecocide and postwar lawsuits, see Zierler, *The Invention of Ecocide* and Martini, *Agent Orange*.

25 For his discussion of DDT, see Edmund Russell, *War and Nature: Fighting Humans and Insects with Chemicals from World War I to "Silent Spring"* (Cambridge, 2001).

and over the summer of that year the administration of US President Richard Nixon worked out plans with Congress to form the Environmental Protection Agency. On April 15, 1970, Nixon ordered a partial ban on the use of the herbicide 2,4,5-T at home; the next day, he ordered the US military to cease flying all missions using Agent Orange in Vietnam. One week later, the first Earth Day became the United States' largest-ever protest, with over 20 million people participating at sites nationwide. The organizers of Earth Day included prominent critics of the war, such as US Senator Gaylord Nelson (D-Wisconsin) and student activists like Denis Hayes, who had led antiwar protests since the mid-1960s. Meanwhile, US bombing in Indochina continued to escalate, especially bombing in Laos and Cambodia, and antiwar protests erupted at American university campuses. The May 4, 1970 protest at Kent State left four students dead and nine wounded when Ohio National Guard troops fired live rounds into the crowd. Five days later, more than 100,000 protested in Washington, and for the remainder of 1970 anti–Vietnam War protests coincided with environmental protests and legislative action, including passage of the Clean Air Act and Clean Water Act.

During that same year, a growing coalition of scientists, especially plant scientists and geneticists, brought long-brimming concerns about Agent Orange to public attention. The American Association for the Advancement of Science (AAAS) had, since 1966, supported a herbicide commission tasked with more scientific research on Operation Ranch Hand and the long-term impacts of herbicides in Vietnam. After a graduate student leaked a 1969 report suggesting that 2,4,5-T caused birth defects in mice, AAAS scientists persuaded the US government to support an investigative mission in Vietnam. In August 1970, they toured defoliated areas of South Vietnam, and months later they published reports calling for an end to the United States' use of herbicides as weapons. David Zierler's *The Invention of Ecocide* details how these scientists worked with sympathetic politicians and antiwar activists to force the end of Operation Ranch Hand in 1971. It also notes that Nixon used the opportunity to score political points by urging the US Senate to finally commit the United States to the 1925 Geneva Protocol banning use of chemical weapons.[26] Over successive years, this organization of scientists galvanized a broader movement of scientists and nongovernmental organizations (NGOs) concerned at the proliferation of chemical, biological, and radioactive weapons. Scientists such as Yale botanist Arthur Galston, one of the first to coin the term "ecocide," forged international connections with scientists in Europe, the Soviet

26 Zierler, *The Invention of Ecocide*, 122–36.

Union, and China to raise public attention about the threat of these unusual weapons. Ultimately, these efforts helped spur the United States and most other nations to sign on to a new treaty, a convention banning environmental modification tactics in warfare, in 1977.

In the last two decades since the US Congress passed the 1991 Agent Orange Act, and with the restoration of diplomatic ties with Vietnam in 1994, both governments have increased their cooperation on a host of lingering environmental problems, especially the removal of unexploded ordnance and the remediation of sites affected by Agent Orange. Besides these formal exchanges, many NGOs such as Peace Trees Vietnam have channeled support, especially from American veterans of the war, to locally focused projects, including the removal of mines and unexploded ordnance, as well as the planting of thousands of trees.[27] The American philanthropy Ford Foundation was a major nongovernment player in supporting dialogues between Vietnamese and American experts over Agent Orange from the establishment of its office in Hanoi in 1991 until 2011, when another philanthropy, the Aspen Institute, took over leading this US–Vietnam dialogue.[28] Because of these long-term reconciliation efforts and mostly open American records, the Vietnam War presents historians with many opportunities to explore the long-term environmental consequences of war.

27 Peace Trees Vietnam; information available online at www.peacetreesvietnam.org/.

28 See the "Ford Foundation's landmark work on Agent Orange transitions to Aspen Institute, May 5, 2011": www.fordfoundation.org/the-latest/news/ford-foundations-landmark-work-on-agent-orange-transitions-to-aspen-institute/. See also the Aspen Institute's "The Agent Orange in Vietnam Program": www.aspeninstitute.org/programs/agent-orange-in-vietnam-program/.

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